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APRIL 10, 1989

CHEMICAL & ENGINEERING

NEWS

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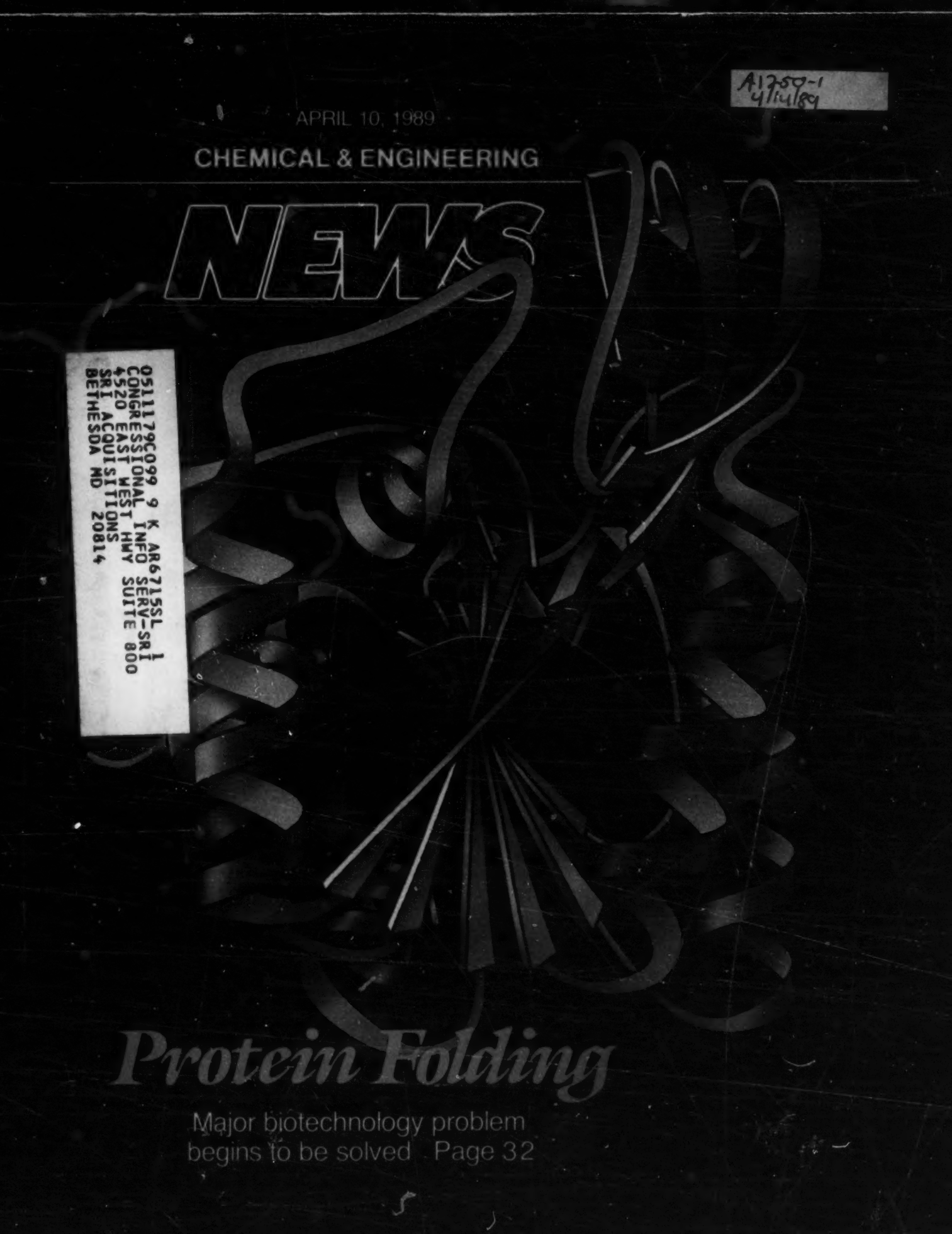

Protein Folding

Major biotechnology problem begins to be solved Page 32

CHEMICAL & ENGINEERING
NEWS

Volume 67, Number 15
CENEAR 67 (15) 1-86
ISSN 0009-2347

APRIL 10, 1989

News of the Week

■ **Scientific community scrambles to explain cold fusion process claimed by two Utah groups.** Page 6

■ **As protest continues over settlement of Union Carbide's 1984 chemical disaster in Bhopal, India's high court holds up disbursement of settlement.** Page 7

■ **Philadelphia-based SmithKline Beckman and the U.K.'s Beecham Group hold merger discussions.** Page 8

■ **University of Chicago researchers find UV radiation at Antarctica increases as ozone hole develops.** Page 8

Business

Top 50 chemicals production hit a record high in 1988, increasing 7.6% to 610 billion lb and putting pressure on existing capacity. **Page 11**

Output of polymers—plastics, synthetic fibers, and synthetic rubber—continued on an upward course, reaching a record 60.4 billion lb last year. **Page 14**

Government

A Carnegie Corp. commission begins effort to examine science advice process, hopes to develop structures, processes useful to political and judicial decision makers. **Page 17**

Department of Energy launches environmental cleanup program that will focus on correcting waste management procedures at its operating facilities. **Page 18**

Science/Technology

Indiana-Purdue chemists develop phase-transfer catalysis procedure for the synthesis of α-amino acids. **Page 25**

Stereolithography, a developing photochemical technology, allows computer-generated designs to be made directly into complex plastic parts. **Page 27**

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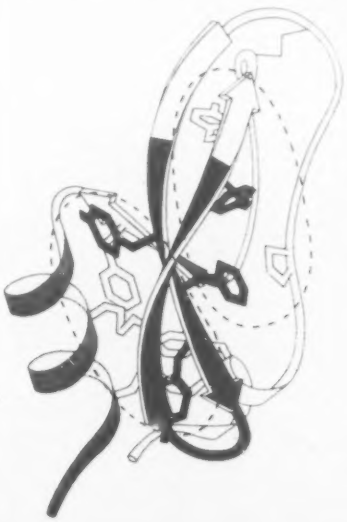
ACS books and journals, together with other scientific publications, will be exhibited abroad beginning this summer; professional liability insurance for ACS members is officially offered. **Page 57**



Cover: Example of folded protein, phosphoglycerate kinase domain 2. Figure courtesy of Jane S. Richardson

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Special Report

As biotechnology unleashes the potential to design and synthesize proteins with functions not currently known, researchers are making inroads in tackling a major unsolved problem in biology and chemistry—how amino acid sequence determines the folding of a polypeptide chain. **Page 32**

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Jeanne M. Shreeve (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Clayton F. Callis; William P. Jencks; Gary J. Long; John H. Nelson; and Louis D. Quin

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Subscription Rates 1989. Printed editions: nonmembers U.S. 1 yr. $55, 2 yr. $99, outside U.S. 1 yr. $86, 2 yr. $161. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Chemical substances

SIR: These days, the phrase "chemical substance" has such pejorative connotations that if it were generally realized that table salt is one of those horrid things, a large section of the populace would go on a salt-free diet. To divulge to a tennis partner that you were formerly a chemist is to be immediately held responsible for all the ills that flesh is heir to; the chemical industry is both literally and figuratively in bad odor with the public. A consequence of this disrepute is the widely held idea that all chemicals are dangerous to your health; some are just worse than others. It follows that chemists should be, in general, weak, sickly persons destined for an early grave. But are they?

Large-scale chemical industry and large-scale academic training of chemists in this country are now about 75 years old, or three generations. Laboratory safety measures have changed over this period from none—handling H_2S, SO_2, and cyanides in unventilated rooms—to the mandatory use of high-velocity hoods for the mere evaporation of common solvents. ACS, the federal census, and the chemical companies must have accumulated during this time detailed data on hundreds of thousands of chemists and chemical workers, and insurance companies must possess detailed data on their morbidity and mortality. Yet, to my knowledge, there has never been a large-scale, long-time study of the professional chemist and the chemical worker as a candidate for unusual liver, kidney, heart, or lung damage. Which is worse: a decade of PCBs, but clean air, in Pittsfield; or a decade of mercaptans and smog in Bayonne or Bay City? Who lives longer: a sloppy organic chemist or a Los Angeles cab driver? Who knows?

The Environmental Protection Agency and the Food & Drug Administration are presently buffeted on all sides in their efforts to set reasonable limits on exposure to chemical substances. For new compounds, given the wide physiological disparities in sensitivity that can arise between humans and experimental animals, this is well-nigh impossible; however, there are also continual controversies over substances as common as benzene or carbon tetrachloride. Why do not the agencies listed above, singly or cooperatively, make use of this immense backlog of experimental animals, of the thousands on thousands of researchers who have spent decades evaporating benzene on hot plates, of electrical workers up to the elbows in PCBs, of dry cleaners who inhaled trichloroethylene for 10 or 20 years? Case histories are notoriously unreliable, but taken in thousands they become statistics, which are deemed eminently reliable by government agencies.

It is ironic that Freon 12, that exemplar of industrial safety and physiological harmlessness, should now be shown to threaten the world. It would also be ironic if some of the old familiar compounds that EPA spends so much time and money on were shown, by a large-scale survey of chemists and chemical workers, to be paper tigers. Such a study would probably not reduce anyone's doctor bills, but it might knock a little off the national debt.

John A. Young
Kerrville, Tex.

Offshore minerals

SIR: The article entitled "Prospects for Offshore Mineral Mining Remain in Doubt" (C&EN, Nov. 7, 1988, page 18) was a welcome and informative exposure to marine minerals and some of the underlying geochemistry for our readership. Unfortunately, several inaccuracies managed to make their way into this otherwise highly interesting and timely feature. I have been involved personally in various aspects of marine minerals research for the past 10 years. This work has allowed me to study hydrothermal systems such as that associated with the Loihi submarine volcano in the Hawaiian Archipelago as well as marine ferromanganese deposits from Hawaii and other regions of the Pacific. If I may, I would like to offer a few comments/corrections to the article.

The feature erroneously reports that chimneys on Loihi reach heights of up to 30 meters; the greatest estimates from deep-sea photography and from submersible observations suggest chimney heights up to a maximum of only 3 feet. Furthermore, although recently sampled active low-temperature vents are presently located at 980 and 1260 meters, other vents were sampled at different locations in 1982 during a previous expedition aboard the *USNS De Steiguer*. These vents may no longer be active, but evidence obtained during the latter project suggested that the nontronite deposits, Fe- and Mg-rich aluminosilicates (not insoluble carbonates as indicated in the C&EN article), formed by direct precipitation from warm metal-rich hydro-

Top 50 Chemicals Production Reaches Record High

Output increased 7.6% in 1988 to 610 billion lb; inorganics turned in strongest showing, climbing 8.5%, as organics increased 5.9%

Marc S. Reisch,
C&EN Northeast News Bureau

Continued export growth and heavy domestic demand made 1988 another good year for U.S. chemical output. According to C&EN's annual ranking of the 50 largest-volume chemical products, total production in that group in 1988 increased a dramatic 7.6% from 1987, surpassing the 600 billion lb mark for the first time to 610 billion lb. That growth rate bettered 1987's increase of 6.5% over 1986. In most cases, 1988 production of basic chemicals could not have been much higher without additional capacity on stream than existed during the year.

According to the U.S. Federal Reserve Board, seasonally adjusted capacity utilization for chemicals and products ranged between 86.1 and 89.2% during 1988. As pressure mounted throughout the year on existing capacity because of the strong domestic economy, prices rose dramatically. From December 1987 to December 1988, the producer price index for chemicals and allied products increased 11.5% to reach 121.7 (1982 = 100), according to the U.S. Department of Labor. For the subcategory of industrial chemicals, prices rose even faster: up 16.2% to an index of 114.1.

In one case, rising domestic demand coupled with the loss of Shell Oil's Norco, La., refinery for part of the year conspired both to cap output of ethylene at a lower level than it would otherwise have been and to increase prices dramatically. The explosion at the refinery on May 5 knocked out 2.2 billion lb of capacity that accounted for a full 6% of U.S. ethylene capacity (C&EN, May 16, 1988, page 4). Department of

About the Top 50 list of chemical products

Government data, trade association figures, and industry estimates all go into preparing C&EN's annual list of the Top 50 chemical products, ranked by production volume. The federal government is relied upon most heavily, but when government figures are not available, other sources, primarily trade associations, are used. Industry sources and C&EN estimates are used only when other data are lacking.

Government data are not always accurate—they are only as good as the information that individual companies report. But they are an objective measure of production extending back many years. Therefore, relatively accurate indications of growth can be made on a consistent basis.

At this time of year, C&EN has access only to preliminary reports of production for 1988. When the government and trade associations issue their final reports, the outcome can be changed, sometimes dramatically. As a result, the production figures for earlier years that appear in the table on page 12 are different in some cases from those published in last year's Top 50 article. The final reports also can affect the rankings of chemicals. For the table published on page 12, the 1987 ranking of only one chemical, potash, is different from last year's listing (C&EN, April 11, 1988, page 31). But production revisions affected the 1986 ranking of 16 chemicals in the table appearing last year.

The list itself covers production figures for the U.S. and includes chemicals produced for export. Candidates for the list include all basic, intermediate, and chemically homogeneous finished products. These range from chemical building blocks like ethylene and propylene to downstream products like vinyl acetate and ethylene glycol.

The roster also includes basic inorganic chemicals but does not include what C&EN considers to be minerals, such as salt, gypsum, and sulfur. Lime is included because it is processed and has many chemical and industrial applications. Refractory (dead burned) dolomite is excluded in the calculations of lime production.

In the organics list, such petrochemical feedstocks as ethane, butane, and propane are excluded arbitrarily because they are considered to be products of oil companies and because they have many nonchemical uses.

There are other gray areas besides lime and petrochemical feedstocks. For example, the basic aromatics—benzene, toluene, and xylene—are included. Admittedly, this makes the list less pure chemically.

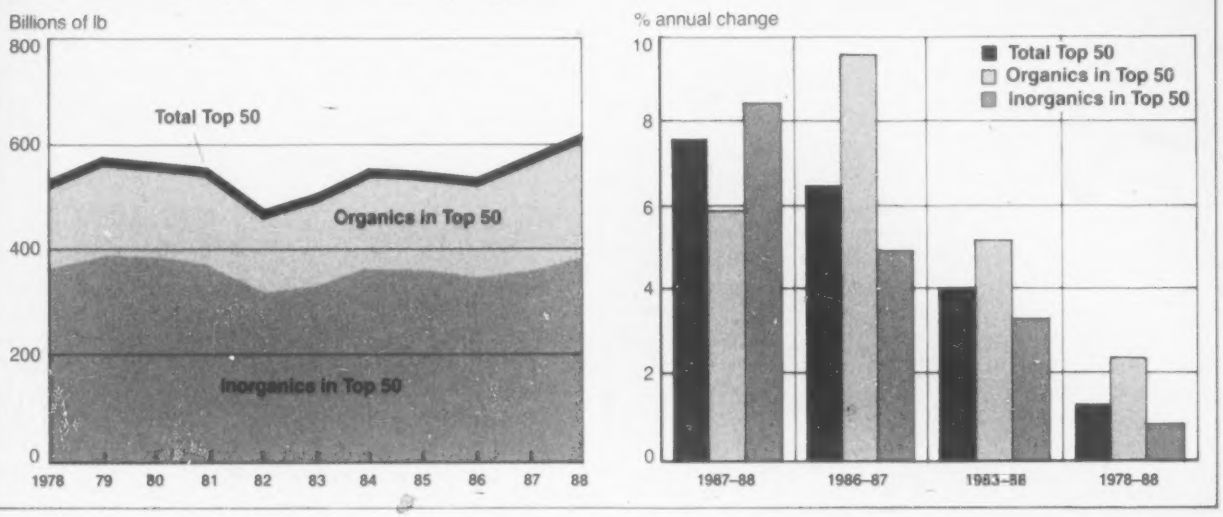
Production figures are published by the government and trade associations in a variety of units—pounds, tons, cubic feet, gallons, metric tons. To provide an accurate ranking and to make comparison of production volumes easier, C&EN lists production not only in common units but converted to pounds as well.

Top 50 chemicals production totaled about 610 billion lb in 1988

Rank 1988	Rank 1987[a]		Billions of lb 1988	Billions of lb 1987	Common units[b] 1988	Common units[b] 1987	Average annual growth 1987–88	1986–87	1983–88	1978–88
1	1	Sulfuric acid	85.56	77.50	42,779 tt	38,750 tt	10.4%	5.2%	2.7%	0.3%
2	2	Nitrogen	52.10	47.39	719 bcf	654 bcf	9.9	−2.5	5.1	6.3
3	5	Oxygen	37.09	32.28	448 bcf	390 bcf	14.9	−2.3	5.3	0.5
4	3	Ethylene	36.56	34.99	36,562 mp	34,992 mp	4.5	6.5	5.0	3.5
5	4	Ammonia	33.89	32.32	16,946 tt	16,161 tt	4.9	15.4	4.0	−0.1
6	6	Lime[c]	32.34	30.36	16,169 tt	15,182 tt	6.5	2.3	1.7	−2.3
7	7	Sodium hydroxide	23.97	23.04	11,983 tt	11,518 tt	4.0	7.7	3.2	0.6
8	9	Phosphoric acid	23.43	20.95	11,717 tt	10,473 tt	11.9	13.8	3.7	2.0
9	8	Chlorine	22.66	21.96	11,329 tt	10,980 tt	3.2	5.2	2.6	0.2
10	10	Propylene	19.97	18.53	19,966 mp	18,527 mp	7.8	12.1	7.4	4.4
11	11	Sodium carbonate[d]	19.10	17.78	9,550 tt	8,891 tt	7.4	5.4	2.4	1.4
12	13	Nitric acid	15.78	14.20	7,889 tt	7,102 tt	11.1	8.2	2.5	−0.1
13	12	Urea[e]	15.76	14.88	7,878 tt	7,441 tt	5.9	23.4	5.6	2.3
14	15	Ammonium nitrate[f]	14.38	12.83	7,188 tt	6,416 tt	12.0	15.5	2.9	0
15	14	Ethylene dichloride	13.65	13.81	13,652 mp	13,805 mp	−1.1	6.7	3.5	2.2
16	16	Benzene	11.84	11.67	1,608 mg	1,585 mg	1.5	16.4	5.5	0.8
17	18	Ethylbenzene	9.94	9.41	9,936 mp	9,409 mp	5.6	4.3	4.8	1.7
18	20	Terephthalic acid[g]	9.60	8.11	9,604 mp	8,110 mp	18.4	5.5	11.3	4.9
19	17	Carbon dioxide[h]	9.38	9.86	4,691 tt	4,932 tt	−4.9	1.0	3.7	4.0
20	19	Vinyl chloride	9.06	8.23	9,056 mp	8,230 mp	10.0	−2.5	5.7	2.7
21	21	Styrene	8.59	8.09	8,588 mp	8,090 mp	6.2	2.6	4.8	1.8
22	22	Methanol	7.34	7.29	7,343 mp	7,292 mp	0.7	1.2	−1.7	1.3
23	24	Formaldehyde[i]	6.73	6.08	6,730 mp	6,077 mp	10.7	9.5	4.3	0.5
24	23	Toluene[j]	6.47	6.73	892 mg	928 mg	−3.9	51.9	2.7	−1.7
25	25	Xylene	5.93	5.72	824 mg	795 mg	3.6	27.6	2.6	−0.3
26	28	Hydrochloric acid	5.87	4.99	2,933 tt	2,495 tt	17.6	3.4	3.9	0.5
27	27	*p*-Xylene	5.60	5.15	5,598 mp	5,152 mp	8.7	2.3	6.4	4.8
28	26	Ethylene oxide	5.37	5.62	5,365 mp	5,623 mp	−4.6	3.6	−0.6	0.5
29	29	Ethylene glycol	4.90	4.52	4,899 mp	4,515 mp	8.5	−5.4	2.1	2.3
30	31	Cumene	4.80	4.15	4,800 mp	4,151 mp	15.6	10.8	7.5	3.6
31	32	Methyl *tert*-butyl ether[k]	4.68	3.37	4,684 mp	3,372 mp	38.9	−0.1	41.0	na
32	30	Ammonium sulfate	4.67	4.37	2,337 tt	2,183 tt	7.1	4.7	3.6	−0.5
33	33	Phenol[l]	3.53	3.24	3,528 mp	3,241 mp	8.9	4.0	6.0	2.8
34	36	Potash[m]	3.35	2.78	1,520 tmt	1,262 tmt	20.4	5.0	1.2	−3.9
35	35	Butadiene[n]	3.19	3.00	3,194 mp	3,002 mp	6.4	15.8	6.3	−1.0
36	34	Acetic acid	3.16	3.23	3,164 mp	3,227 mp	−2.0	18.3	2.4	1.3
37	38	Propylene oxide	3.11	2.61	3,110 mp	2,608 mp	19.2	5.2	10.8	4.3
38	37	Carbon black	2.92	2.72	2,916 mp	2,724 mp	7.0	5.4	3.2	−1.4
39	41	Aluminum sulfate	2.59	2.45	1,297 tt	1,223 tt	6.1	0.1	3.3	−0.1
40	39	Acrylonitrile	2.58	2.55	2,576 mp	2,551 mp	1.0	16.9	3.7	3.9
41	40	Vinyl acetate	2.56	2.51	2,561 mp	2,505 mp	2.2	46.5	−5.5	4.2
42	42	Cyclohexane	2.32	2.25	2,319 mp	2,250 mp	3.1	8.6	7.0	−0.1
43	43	Acetone	2.29	2.08	2,285 mp	2,082 mp	9.8	7.5	4.2	−1.0
44	44	Titanium dioxide	2.04	1.90	1,021 tt	952 tt	7.2	2.3	6.2	3.8
45	46	Sodium sulfate[o]	1.69	1.61	845 tt	805 tt	5.0	3.9	−0.2	0.4
46	44	Sodium silicate	1.64	1.90	821 tt	952 tt	−13.8	21.1	2.4	−0.1
47	47	Adipic acid	1.59	1.57	1,588 mp	1,572 mp	1.0	3.3	4.4	−0.2
48	49	Isopropyl alcohol	1.42	1.31	1,418 mp	1,313 mp	8.0	0.9	3.2	−2.0
49	48	Calcium chloride[p]	1.31	1.55	657 tt	773 tt	−15.0	−0.9	−5.2	−4.4
50	50	Caprolactam	1.26	1.16	1,261 mp	1,161 mp	8.6	4.7	5.2	3.2
TOTAL ORGANICS			213.79	201.87			5.9%	9.6%	5.2%	2.4%
TOTAL INORGANICS			395.76	364.76			8.5%	4.9%	3.3%	0.8%
GRAND TOTAL			609.55	566.63			7.6%	6.5%	4.0%	1.3%

a Revised. b tt = thousands of tons, bcf = billions of cubic feet, mp = millions of pounds, mg = millions of gallons, tmt = thousands of metric tons. c Except refractory dolomite. d Natural and synthetic. e 100% basis. f Original solution. g Includes both acid and ester without double counting. h Liquid and solid only. i 37% by weight. j All grades. k Production data for earlier years unavailable. l Synthetic only. m K_2O basis. n Rubber grade. o High and low purity. p Solid and liquid. na = not available.

Production of Top 50 chemicals up again



Labor figures show that ethylene prices rose 69% between December 1987 and December 1988 to an index of 178.8.

Ethylene was not the only commodity under capacity restrictions. Sodium hydroxide producers, for instance, operated at record levels throughout 1988 (C&EN, Aug. 8, 1988, page 20). As supplies of sodium hydroxide tightened, prices climbed. During the year, sodium hydroxide prices increased 49% to an index of 85.9, according to the Department of Labor.

The low U.S. dollar relative to most foreign currencies at least kept U.S. chemical producers competitive with overseas manufacturers in most cases. However, because of the increase in domestic prices, many of the chemical bargains that drove production for export in 1987 did not exist in 1988. On the domestic front, demand for chemicals in housing and the auto market continued strong as these industries turned increasingly to chemical-based adhesives in place of metal fasteners, to plastics in place of steel auto body components, or to vinyl siding for housing in place of wood. Fertilizer demand was good despite drought conditions in most of the country, as fertilizer purchases and application were made in advance of the drought's effects.

Among the largest-volume chemicals produced in the U.S., sulfuric acid remained on top with total production of 85.6 billion lb, a 10% increase from 1987. Nitrogen continued to rank a distant second, with production at 52.1 billion lb, up 9.9% from 1987. That was a better showing than in 1987, when production declined 2.5%.

Organic chemicals, comprising some 35% of the Top 50, made a good showing in 1988 but growth did not do so well as it did in 1987. Production of those substances increased 5.9% in 1988 compared with a 9.6% year-to-year increase in 1987. Between 1983 and 1988, production of organic chemicals among the Top 50 increased an average of 5.2% a year. Over the long term, however, their output has grown at a much slower pace. Between 1978 and 1988, output of organic chemicals among the Top 50 grew at a compound annual rate of only 2.4% a year.

However, the inorganic segment of the Top 50 increased markedly in 1988. Production grew 8.5%, following a 4.9% increase in 1987. Within this category, production grew for major fertilizer chemicals—including phosphoric acid, up 12%; urea, up 5.9%; and potash, up 20%. Other big-volume inorganics also showed improvements. Hydrochloric acid production increased almost 18%, and ammonium nitrate production increased 12%.

Of the Top 50 chemicals, production of 43 of them increased in 1988. By contrast, production of 44 increased in 1987. Total production of the Top 50 chemicals, at 610 billion lb, was up 7.6% from 1987 and exceeded the historical high of 575 billion lb in 1979 by 6.1%. The 1988 production level was 32% higher than the decade-low level of 464 billion lb registered in 1982.

For the Top 50 group, composite output increased at a compound annual rate of 4.0% between 1983 and 1988. Indicative of long-term growth, Top 50 production grew at an average annual rate of 1.3% between 1978 and 1988.

As a group, inorganic chemicals outperformed the organics. Showing the largest production gain on the inorganics side was potash, up 20% from 1987 to 3.35 billion lb. The gain pushed potash from 36th place in 1987 to 34th place in the 1988 rankings.

Next in terms of percentage gains among the inorganics was hydrochloric acid, up almost 18% to 5.87 billion lb. The gain placed the chemical 26th in the 1988 list compared with its 28th place showing in the 1987 rankings.

Also showing very good production increases in 1988 were oxygen, up 15% to 37.09 billion lb following a 2.3% decline in the previous year; and ammonium nitrate, up 12% to 14.38 billion lb, following a 16% rise in the previous year.

Other large-volume inorganic chemicals that had large increases in production last year were phosphoric acid, up 12% to 23.43 billion

lb following a 14% increase the year before; and nitric acid, up 11% to 15.78 billion lb following an 8.2% increase the year before.

But although the inorganics as a group registered the largest percentage increases in 1988, a few chemicals in the group showed the largest annual decline in the Top 50 list. Calcium chloride production dipped 15% last year to 1.31 billion lb, following a 0.9% decline a year ago. Sodium silicate production registered a remarkable 14% decline in 1988 to 1.64 billion lb, following close on the 21% increase in production for 1987. Carbon dioxide production also slipped 4.9% in 1988 to 9.38 billion lb following a 1.0% rise in 1987.

For organic chemicals, 1988 production growth was led by terephthalic acid, up 18% from 1987 to 9.60 billion lb. As a result, terephthalic acid moved from 20th place in the 1987 ranking to 18th place in the 1988 list. Cumene also showed good growth in 1988, up 16% to 4.80 billion lb. As a result, cumene also improved its position in the rankings and moved from 31st in the 1987 listing to 30th in the 1988 list.

On the downside of production, leading the products with the largest individual decreases over the five-year period was calcium chloride, whose output fell at an annual compound rate of 5.2%. Other chemicals registering production declines over the five-year period were methanol, down 1.7%, and ethylene oxide, down 0.6%.

Looking at growth over the past 10 years, 32 of the Top 50 chemicals have recorded overall production increases. The best long-term performer has been nitrogen, whose output grew at an annual compound rate of 6.3% during the period. Production of terephthalic acid also grew at a good rate of 4.9%. Other chemicals with sizable growth rates were *p*-xylene, up 4.8%; propylene, up 4.4%; and propylene oxide, up 4.3%. Calcium chloride registered the largest average annual rate of decline over the past 10 years. Its output has fallen at a compound annual rate of 4.4%. □

Polymer output rises for sixth consecutive year

Overall production of plastics, synthetic fibers, and synthetic rubber polymers reached a record high of 60.4 billion lb in 1988. The growth marked the sixth consecutive annual increase for the product group, lifting the output total 6.0% above the 1987 record.

Plastics, which account for more than three quarters of the polymer group production totals, continued excellent growth in 1988. Production was up 6.7% from 1987—a respectable showing, but not so strong as the 9.8% annual growth in 1987.

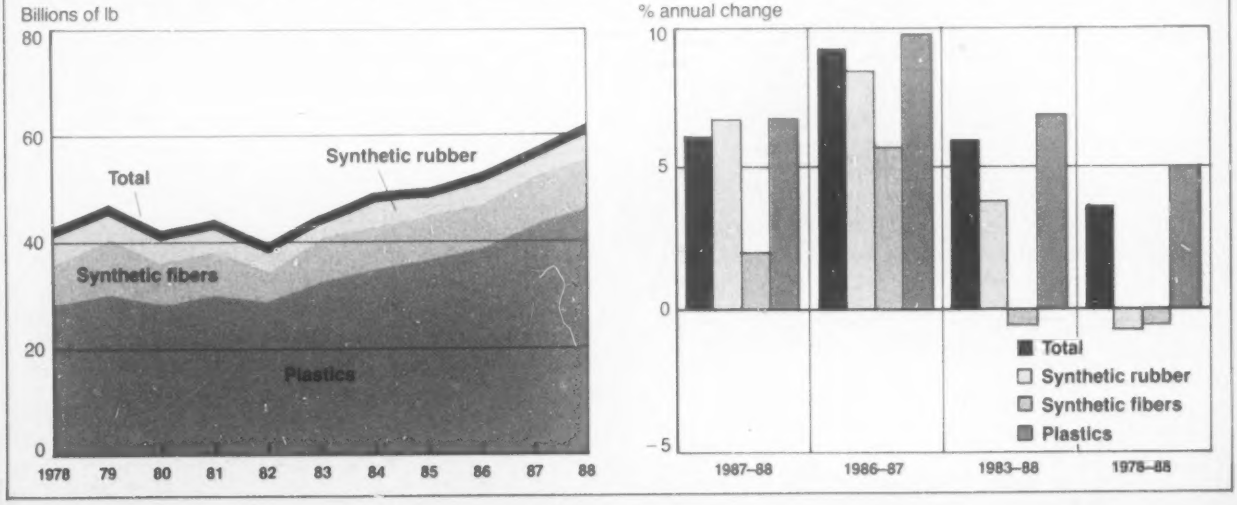
The strongest growth among plastics was registered by the thermoplastic resins, whose output rose 6.9% last year. Of such resins, production of polypropylene continued to show the highest growth, up 9.4%, followed by low-density polyethylene with 8.3%, polystyrene with 7.3%, high-density polyethylene with 5.1%, and polyvinyl chloride and copolymers with 4.8%.

By comparison, output of thermosetting resins grew 5.3% in 1988. Unmodified epoxies exhibited the most remarkable growth, up 14% from 1987 following an 8.8% increase in 1987. Among other thermosetting resins, production of phenol and other tar acid resins grew 6.8% in 1988; urea resins, 3.1%; and unsaturated polyesters, 2.6%.

Melamine resins output, which showed such spectacular growth in 1987, declined in 1988. Melamine resin production dropped to 207 million lb last year, a 2.4% decline from the previous year when output of 212 million lb was almost 23% ahead of production levels in 1986.

For the five-year period 1983–88,

Output of plastics, synthetic fibers, and synthetic rubber continued to climb in 1988



Total polymer output exceeded 60 billion lb last year

	Billions of lb		Common units					Average annual growth			
	1988	1987	1988	1987	1986	1983	1978	1987–88	1986–87	1983–88	1978–88
PLASTICS (millions of lb)											
Thermosetting resins	**6.60**	**6.27**	**6,597**	**6,265**	**5,834**	**5,254**	**4,449**	**5.3%**	**7.4%**	**4.7%**	**4.0%**
Phenol and other tar acid resins	3.07	2.87	3,066	2,870	2,721	2,484	1,617	6.8	5.5	4.3	6.6
Urea resins	1.43	1.38	1,425	1,382	1,271	1,172	1,122	3.1	8.7	4.0	2.4
Polyesters (unsaturated)	1.40	1.37	1,404	1,368	1,271	1,084	1,209	2.6	7.6	5.3	1.5
Epoxies (unmodified)	0.50	0.43	495	433	398	334	299	14.3	8.8	8.2	5.2
Melamine resins	0.21	0.21	207	212	173	180	202	−2.4	22.5	2.8	0.2
Thermoplastic resins	**39.55**	**36.99**	**39,549**	**36,992**	**33,569**	**27,799**	**23,932**	**6.9%**	**10.2%**	**7.3%**	**5.2%**
Low-density polyethylene	10.40	9.60	10,398	9,599	8,888	8,041	7,111	8.3	8.0	5.3	3.9
PVC and copolymers	8.35	7.97	8,350	7,971	7,256	6,066	5,723	4.8	9.9	6.6	3.8
High-density polyethylene	8.40	8.00	8,399	7,995	7,171	5,691	4,201	5.1	11.5	8.1	7.2
Polystyrene[a]	5.13	4.78	5,130	4,780	4,442	3,567	3,823	7.3	7.6	7.5	3.0
Polypropylene	7.27	6.65	7,272	6,647	5,812	4,434	3,074	9.4	14.4	10.4	9.0
TOTAL[b]	**46.15**	**43.26**	**46,146**	**43,257**	**39,403**	**33,053**	**28,381**	**6.7%**	**9.8%**	**6.9%**	**5.0%**
SYNTHETIC FIBERS (millions of lb)											
Cellulosics	**0.61**	**0.61**	**614**	**605**	**619**	**640**	**905**	**1.5%**	**−2.3%**	**−0.8%**	**−3.8%**
Rayon	0.40	0.41	400	414	404	411	597	−3.4	2.5	−0.5	−3.9
Acetate[c]	0.21	0.19	214	191	215	229	308	12.0	−11.2	−1.3	−3.6
Noncellulosics[b]	**8.49**	**8.32**	**8,489**	**8,316**	**7,828**	**8,701**	**8,691**	**2.1%**	**6.2%**	**−0.5%**	**−0.2%**
Polyester[d]	3.68	3.54	3,679	3,541	3,305	3,543	3,800	3.9	7.1	0.8	−0.3
Nylon	2.67	2.69	2,666	2,689	2,514	2,418	2,550	−0.9	7.0	2.0	0.4
Olefin[e]	1.56	1.49	1,556	1,494	1,393	902	692	4.1	7.3	11.5	8.4
Acrylic[f]	0.59	0.59	588	592	616	671	726	−0.7	−3.9	−2.6	−2.1
TOTAL[b]	**9.10**	**8.92**	**9,103**	**8,921**	**8,447**	**9,341**	**9,596**	**2.0%**	**5.6%**	**−0.5%**	**−0.5%**
SYNTHETIC RUBBER (thousands of metric tons)											
Styrene-butadiene[g]	1.98	1.87	900	850	792	904	1,395	5.9	7.3	−0.1	−4.3
Polybutadiene	0.90	0.82	407	371	336	333	378	9.7	10.4	4.1	0.7
Ethylene-propylene	0.58	0.56	263	254	230	175	174	3.5	10.4	8.5	4.2
Nitrile	0.17	0.15	76	69	59	55	73	10.1	16.9	6.7	0.4
Other[h]	1.50	1.41	679	638	596	468	454	6.4	7.0	7.7	4.1
TOTAL[b]	**5.13**	**4.81**	**2,325**	**2,182**	**2,013**	**1,935**	**2,474**	**6.6%**	**8.4%**	**3.7%**	**−0.6%**

a No longer includes acrylonitrile-butadiene-styrene or styrene-acrylonitrile resins; historical data are restated. b Totals are for those products listed. Totals may not add because of rounding. c Includes diacetate and triacetate yarn, but does not include cigarette tow. Beginning with 1985, includes rayon yarn. d Excludes aramid after 1982. e Includes olefin film, olefin fiber, spun-bonded polypropylene, and vinyon. f Includes modacrylic. g Excludes high-styrene latex. h Beginning with 1985, includes neoprene; historical data are restated. Also includes butyl; polyisoprene; chlorosulfonated polyethylene; polyisobutylene; and acrylo, fluoro, and silicone elastomers. **Sources:** Society of the Plastics Industry, Textile Economics Bureau, Rubber Manufacturers Association

the plastics segment grew at an annual compound rate of 6.9%. For the 10-year period between 1978 and 1988, plastics grew at an annual compound rate of 5.0%.

Output of synthetic rubber, another polymers segment, increased 6.6% in 1988. Production of 5.1 billion lb last year was the best showing from the category since 1979, when production reached 5.6 billion lb. Output is still running 9.8% below the decade high reached in 1979.

All segments of the synthetic rubber category registered increases in production in 1988. Just as it did in 1987, nitrile rubber registered the largest increase, with production rising 10% last year, following its spectacular 1987 growth of 17%. Polybutadiene output grew 9.7% last year.

Other categories did less well but still grew. Styrene-butadiene rubber production increased 5.9% in 1988, followed by ethylene propylene output, up 3.5%.

Over the past five years, the synthetic rubber category has grown at a compound annual rate of only 3.7%. For the past 10 years, production has actually declined at an average annual rate of 0.6%.

For another polymers group, synthetic fibers, the respectable performance put in for 1987 was not repeated for 1988. Although the yearly production growth in 1987 was 5.6%, growth last year slowed to just 2.0%. Though the volume of imported textiles has stabilized, U.S. textile producers have yet to regain the share of market they held only a few years ago.

The noncellulosics group, which accounts for more than 90% of synthetic fiber production in the U.S., grew 2.1% in 1988. The growth leader was olefin, up 4.1% compared with the year-earlier level, followed by polyester, up 3.9%. Nylon and acrylic production declined marginally, down 0.9% and 0.7%, respectively.

The cellulosics group recorded a marginal gain of 1.5% in 1988 following the 2.3% decline in 1987. Rayon production slipped 3.4% as a result of a temporary shutdown of the Avtex fiber complex in Front Royal, Va. Acetate production increased 12% as replacements for triacetate fiber, withdrawn from production a few years ago, have now come into the market.

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